MULTIUSE SPACE VEHICLE – WO 2005/077759 A1 Publication

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Field of the Invention

The invention relates to space technology, mainly to reusable space vehicles for reentry and descending in a planet atmosphere.

Background of the Invention

Spacecraft of a truncated cone configuration are known. The first American spacecraft Mercury may be cited as an example of such a spacecraft (Fig. 1) [1]. Since then, such structures are referred to as capsule type spacecraft. Once de-orbited, such a capsule, configured as a truncated cone, is flying with its wide part forward, and a spherical heat shield covering the spacecraft (SC) wide part can be jettisoned after atmospheric braking. The Mercury heat shield was jettisoned, but not separated completely, and a honeycomb damper was extended to cushion a splashdown impact. The Soyuz SC heat shield was completely jettisonable, whereas the Gemini and Apollo heat shields were not jettisoned at all [2]. The reason to configure a spacecraft (capsule) as a truncated cone flying with its wide part forward and covered with a heat shield stems from a number of factors, specifically:

- Features in a favorable distribution of heat flows as compared, for example, to a sphere or a cone flying with its pointed part forward; actually, such shield serves as a wake shield, forming a shock-wave (Fig. 2); under certain conditions (when flying at an angle of attack) the spacecraft (capsule) acquire a lift/drag ratio;
- With an angle of attack the capsule descent in atmosphere is controlled at supersonic velocities through roll maneuvers requiring small reaction control engines;
- Good volumetric configuration and internal layout;

- Easily integrated with a launch vehicle (LV) fitting well into a streamlined upstage;
- A direction of overloads is favorable for the crew during the ascent phase (on LV), and during re-entry, as well as at landing.

Experience gained from the development of American spacecraft Mercury and Gemini [3] suggests that the capsule exterior shell can be made of heat-resistant metal alloys; upon recovery, the capsule remains fit for reuse. This had been practically proved during the Gemini-2 mission; its capsule had been re-used again in 1966 within the MOL Program (orbital station project that had been cancelled later) [4].

A drawback of the capsule type SC is a low lifting force, the so-called low lift/drag ratio. This drawback reveals itself felt during return from space in the both main flight phases: during atmospheric braking and, particularly, at landing. In the first case, this results in limited cross range capabilities, in the second case this makes impossible to land on a runway as an aircraft. Consequently, all capsule type spacecraft has been landed on parachutes.

To land to a runway a rather high lift-to-drag ratio is required. When developing the first reusable spacecraft Space Shuttle (Figs. 3a, 3b, 3c), this was precisely a motivation behind the decision to choose a configuration with a delta wing ensuring a high stability and a large cross range maneuverability against other wing configurations [5]. The main goal was to land the "orbiter" (the retrievable element of STS – Space Transportation System – Space Shuttle) to a

runway due to a high lift-to-drag ratio, both at supersonic velocities (for a cross range maneuverability) and at subsonic velocities (during final approach and landing).

There is a great contradiction between the desirable spacecraft configurations for different flight phases: insertion into orbit on a launch vehicle (LV), descent, and landing. At hypersonic velocities (particularly, at large Mach numbers) the winged configuration, though ensuring a large cross range maneuver, is not efficient as a whole, specifically, very large surfaces of SC require special heat protection. An additional requirement for multiuse increases the mass of the thermal protection system (the total mass of the Space Shuttle orbiter tiles is about 9 tons) and complicates its configuration, design, and processing. To integrate such a spacecraft with an LV also becomes more difficult. The main shortcomings of the spacecraft wings are also manifested in the following. During insertion into orbit the wings bring serious safety problems. So, the Space Shuttle orbiter wings are prone to a risk of damage during ascent and descent that, after all, has resulted in the Columbia loss caused by a damage of the wing by a piece of the thermal insulation slipped from the external tank.

Once de-orbited, during atmospheric braking, the winged Orbiter is "compelled" to fly with its fuselage bottom (belly) forward to save, first of all, the nose cup, leading edges of wings, and of stabilizer from overheating. Moreover, in such a configuration, during atmospheric braking, the Orbiter proves to be a poorly controllable spacecraft, having a low stability margin that makes it rather sensitive

to damages. This shortcoming has been in particular exhibited in the last mission of Columbia.

The thermal protection system of the Orbiter is made as special blankets and tiles, covering the whole structure and protecting it from overheating. Most of the tiles, which total number exceeds 27 000, are cemented to the body. Besides a large mass, the tiles are expensive, technologically ineffective, and their in-flight monitoring and turnaround processing is labored and time-consuming.

G-loads to which the Space Shuttle crew is exposed during ascent on LV and landing are of different direction, and that presents more difficulties.

Also known are spacecraft designed as a lifting body with tilting stabilizers (Figs. 4a, 4b, 4c). A spacecraft of such configuration was considered as an option in the Space Shuttle early design phase [5]. Spacecraft of the lifting body type are smaller in size, offer a good stability but a mean lift/drag ratio, giving the ability to maneuver in atmosphere and probably land on a runway. However, this kind of design suffers from the same shortcomings as Space Shuttle. To make sea-born aircraft smaller the folding wings are widely used.

In an attempt to reduce the thermal protection system of a spacecraft to ensure re-entry it was also proposed to employ the folding wings [5]. Specifically, with such approach the spacecraft was designed as a lifting body vehicle with tilting stabilizers that grows into a winged structure (Figs. 5a, 5b, 5c, 5d). This spacecraft is taken as a prototype of the invention.

However, the idea to employ the foldable wings and stabilizers on the retrievable spacecraft turned to be practically unfeasible, because of their inefficiency without additional measures.

Summary of the Invention

It is an objective of this invention to combine both a rather high lift/drag ratio and effective protection of the spacecraft against aerodynamic and heat loads during atmospheric braking at high supersonic velocities, with minimal mass and material spending, including turnaround processing. The objective is achieved by a reusable spacecraft containing a body with wings and/or stabilizers and a front heat shield installed on the afterbody end, covering the end of the body with wings and/or stabilizers during atmospheric braking, the unfolding wings and/or stabilizers being provided with deployment mechanisms to make the spacecraft, first of all the heat shield, smaller. The jettisonable front heat shield covering the foldable wings and/or stabilizers, as well as other parts of the body, is made oval in projection to a plane normal to the longitudinal axis, e.g. ellipse-shaped. In this case, the front heat shield size and mass are reduced, and the spacecraft can acquire an improved lift/drag ratio. The lateral surfaces of a spacecraft covered with the front heat shield are also exposed to aerodynamic loads, including thermal loads, though less violent in comparison with the loads to the front heat shield. To achieve the required aerodynamic forms of the body it is also proposed to employ additional aerodynamic shrouds. Like the front heat shield, the aerodynamic shroud is jettisoned before wings and/or stabilizers are deployed.

The shroud also improves protection against aerodynamic loads, both during descent and ascent on LV. In this case, an additional faring is not required for LV.

The most realistic and tested in practice are spacecraft employing a circular, sphere-shaped front heat shield and a body comprising of sections shaped as a

regular truncated cones. Therefore, the configuration of aerodynamic shroud forming a cone-shaped shroud is acceptable. Generally, a shroud can be of a more complex, oval-shaped configuration.

In this way it became possible to eliminate the aforesaid shortcomings and take advantages of the both retrievable spacecraft (capsule and winged). On the whole, a spacecraft is proposed that is well protected during atmospheric braking at hypersonic velocities (at high Mach numbers), but that acquires a rather high lift/drag ratio after stabilizers and/or wings are deployed; and thus, additional maneuvering and good gliding for landing on a runway are provided due precisely to these design features.

An area of the spacecraft lateral surfaces, including wings and stabilizers, is larger than the heat shield area; therefore the front heat shield mass is much less than the thermal protection mass of lateral surfaces. The additional weigh saving can be achieved by the ablative front heat shield.

The proposed spacecraft (like the famous innovation by Singer – in his machine, sewing with its needle eye first) is flying with its tail-end first during atmospheric braking. An essential effect is thus achieved: the spacecraft body is well protected against major aerodynamic and heat loads. In consequence, the main exterior shell of the spacecraft body can be made of heat-resistant alloys, not requiring an additional heat protection, such as technologically ineffective tiles. Such a spacecraft is remarkable in a more simple design, including easy inspection and maintenance, while being reusable.

As previously noted, the ideas to fold stabilizers and wings have not been materialized on spacecraft until now, because the required efficiency is not achievable without additional measures. With the foldable protruded structure elements the configuration efficiency is greatly improved only in combination with their protection against aerodynamic and heat loads provided by the front heat shield. Folding the wings, stabilizers, and other protruded structural elements enables not only to decrease the spacecraft dimensions to fit them into the heat shield envelope, but also to make smaller the front heat shield itself, while improving the whole configuration and other characteristics. For that, the wings are provided with deployment mechanisms. Stabilizers of the lifting-body spacecraft are made foldable and also provided with deployment mechanisms.

Brief Description of the Drawings

Figs. **6a, 6b, 6c – 13a, 13b, 13c** show the winged spacecraft and lifting-body spacecraft (with stabilizers), respectively, according to the given invention, where:

1 – spacecraft body

2 – wings

3 – stabilizers

4 – jettisonable front heat shield

5 – wing deployment mechanism

6 – stabilizer deployment mechanism

7 – jettisonable aerodynamic shroud

Detailed Description of the Preferred Embodiments

Figs. **6a, 6b, 6c** show a winged spacecraft, which wings **2** are folded during ascent and in orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** together with folded wings **2** and vertical stabilizer **3** are protected by jettisonable front heat shield **4**, for example, of a circular form in projection to a plane normal to the longitudinal axis; the heat shield is jettisoned after atmospheric braking, and wings **2** are deployed with mechanism **5**.

Figs. **7a, 7b, 7c** show a lifting-body spacecraft, which stabilizers **3** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** together with the folded stabilizers are protected by jettisonable front heat shield **4**, for example, of a circular form in projection to a plane normal to the longitudinal axis; the heat shield is jettisoned after atmospheric braking, and stabilizers **3** are deployed with mechanism **6**.

Figs. **8a, 8b, 8c** show a winged spacecraft, which wings **2** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** together with wings **2** and vertical stabilizer **3** are protected by jettisonable front heat shield **4**, oval-shaped in projection to a plane normal to the longitudinal axis; the heat shield is jettisoned after atmospheric braking, and wings **2** are deployed with mechanism **5**.

Figs. **9a, 9b, 9c** show a lifting-body spacecraft, which stabilizers **3** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** together with the stabilizers are protected by jettisonable front heat shield **4**, oval-shaped in projection to a plane normal to the

longitudinal axis; the heat shield is jettisoned after atmospheric braking, and stabilizers **3** are deployed with mechanism **6**.

Figs. **10a, 10b, 10c** show a winged spacecraft, which wings **2** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** together with wings **2** and stabilizer **3** are protected not only with jettisonable front heat shield **4**, but also with aerodynamic shroud **7**, separating after atmospheric braking, and wings **2** are deployed with mechanism **5**.

Figs. **11a, 11b, 11c** show a lifting-body spacecraft, which stabilizers **3** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** and stabilizers **3** are protected not only with the jettisonable front heat shield, but also with the aerodynamic shroud, separating after atmospheric braking, and stabilizers **3** are deployed with mechanism **6**. The aerodynamic shrouds can be also employed on spacecraft, which tail-end, including stabilizers and wings, are protected with the front heat shield, oval-shaped in projection to a plane normal to the longitudinal axis.

Figs. **12a, 12b, 12c** show a lifting-body spacecraft, which stabilizers **3** are folded during ascent and orbital flight, as well as while de-orbiting and atmospheric braking. The tail-end of body **1** and stabilizers **3** are protected not only by jettisonable front heat shield **4** oval-shaped in projection to a plane normal to the longitudinal axis, but also by aerodynamic shroud **7** jettisoned after atmospheric braking, and stabilizers **3** are deployed with mechanism **6**.

Similar aerodynamic shrouds can be also employed on spacecraft with foldable wings, which tail-end, together with stabilizers and wings, is protected

with the front heat shield, oval-shaped in projection to a plane normal to the longitudinal axis. Just as in designing the capsule-type spacecraft, which body configuration comprising several sections of a figure of revolution form (truncated cone and cylinder) was employed, such a form can be also applied for the preferred spacecraft with the bearing frame and foldable wings and/or stabilizers. This can be attained through choosing the shape and configuration of the aerodynamic shrouds forming a conical surface of revolution (Figs. **13a, 13b, 13c**).

Commercial Application

Thus, the spacecraft proposed, in all its options, is well protected. As a result, the outside skin of the spacecraft body and the wings and stabilizers can be made of heat resistant alloys without using additional thermal protection. In addition the tail part of the body including the wings and stabilizers are protected against the most heavy aerodynamic and heat loads and also random damages during insertion into orbit as well as during atmospheric braking when returning from space. Especially this kind of protection could be effective when returning a winged spacecraft into the Earth atmosphere at escape speed after coming back from an interplanetary mission.

The detachable heat front shield is a dispensable element that is why its thermal protection could be of an effective ablative type for example. The aerodynamic shroud bears much less thermal loads and could be made of heat resistant materials.

List of References:

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